An Anthropometric Index Capable of Differentiating Morbid Obesity from Obesity and Metabolic Syndrome in Children

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***Abstract*—**Circumference measurements may give meaningful information about the varying stages of obesity. Some formulas may be derived from a number of body circumference measurements to estimate body fat. Waist (WC), hip (HC) and neck (NC) circumferences are currently the most frequently used measurements. The aim of this study was to develop a formula derived from these three anthropometric measurements for the differential diagnosis of morbid obesity with and without metabolic syndrome (MetS), MOMetS+ and MOMetS-, respectively. 187 children were recruited from the pediatrics outpatient clinic of Tekirdag Namik Kemal University, Faculty of Medicine. Signed informed consent forms were taken from the participants. The study was carried out according to the Helsinki Declaration. The study protocol was approved by the institutional non-interventional ethics committee of Tekirdag Namik Kemal University Medical Faculty. The study population was divided into four groups as normal-body mass index (N-BMI) (n = 35), obese (OB) (n = 44), morbid obese (MO) (n = 75) and MetS (n = 33). Age- and gender-adjusted BMI percentile values were used for the classification of groups. The children in MetS group were selected based upon the nature of the MetS components described as MetS criteria. Anthropometric measurements, laboratory analysis and statistical evaluation confined to study population were performed. BMI values were calculated. A circumference index, advanced Donma circumference index (ADCI) was presented as WC*HC/NC. The statistical significance degree was chosen as $p < 0.05$. BMI values were 17.7 ± 2.8, 24.5 ± 3.3, 28.8 ± 5.7, 31.4 ± 8.0 kg/m^2, for N-BMI, OB, MO, MetS groups ($p = 0.001$), respectively. An increasing trend from N-BMI to MetS was observed. However, the increase in MetS group compared to MO group was not significant. For the new index, significant differences were obtained between N-BMI and OB, MO, MetS groups ($p = 0.001$). A significant difference between MO and MetS groups was detected ($p = 0.043$). A significant correlation was found between BMI and ADCI. In conclusion, in spite of the strong correlation between BMI and ADCI values obtained when all groups were considered, ADCI, but not BMI, was the index, which was capable of differentiating cases with morbid obesity from cases with morbid obesity and MetS.

***Keywords*—**Anthropometry, body mass index, childhood obesity, body circumference, metabolic syndrome.

I. Introduction

OBESITY is an important risk factor for type 2 diabetes (T2D), cancer and cardiovascular diseases (CVDs). Morbid obesity is the ultimate stage often associated with a set of symptoms pointing out the MetS. When this is the case, it is indispensable to diagnose each of these obesity steps as well as MetS. The diagnosis is based on anthropometric measurements as well as indices associated with adiposity and distribution type. They are used for risk identification. They are also called anthropometric health indicators [1].

BMI is the most commonly used anthropometric index to estimate the overall body fatness. However, this index is a measure of excess weight rather than excess body fat mass [1]. Besides, BMI was reported as an index that should not be used to classify pediatric population [2].

Waist circumference (WC) is a simple and practical anthropometric index [3] and well-correlated with body fat percentage (BFP) [4]. Therefore, it was used to identify obesity in both adults and children [5]-[9]. It is one of the main components of MetS as the indicator of central obesity [10], [11]. It is also an important cardiovascular risk factor [12]-[15] and related to T2D [16]-[18].

Hip circumference (HC) is also a simple anthropometric measurement. It is commonly evaluated along with WC. They are commonly used together in many indices and ratios for the evaluation of many pathologies such as obesity, CVDs and diabetes [19]-[22].

Neck circumference (NC), like WC, is also a marker of adipose tissue distribution and used in both adults and children. This parameter was introduced as a simple, useful, accurate anthropometric screening marker of being overweight and obesity [6]-[9].

Although there are many anthropometric measurements and/or ratios, any suitable formula for the evaluation of obesity and the differentiation of the obesity stages such as obesity, morbid obesity and MetS could not be detected based upon the wide-scoped literature survey performed. The aim of this study was to develop and present such an index for the purpose of diagnosing MetS cases.

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II. Patients and Methods

A. Patients

The study was performed on 187 children and four groups, which were composed of children with N-BMI (n = 35), obesity (n = 44), morbid obesity (n = 75) and MetS (n = 33). These groups were called Group 1, 2, 3 and 4, respectively.

B. Informed Consent Forms, Ethics Committee Approval and Helsinki Declaration

Parents of the children have filled and signed the informed consent forms concerning the information related to the present study. The institutional ethics committee approval was obtained for the present research conducted. The Declaration of Helsinki developed by The World Medical Association as a statement of ethical principles for medical research involving human subjects was followed in the study.

C. Definitions for Obesity and Morbid Obesity

Classes were constituted according to age- and gender-adjusted BMI percentile values recommended by World Health Organization [23]. Tables prepared for the purpose were used, and obesity was defined as the 99th and 95th percentiles, and morbid obesity as values above the 99th percentile. Children between the 85th and 15th percentiles were included in Group 1.

D. Criteria for MetS

The central obesity determined by WC was defined as an important determinant of MetS. Plus any two of the following were sufficient to diagnose MetS: Raised fasting blood glucose (FBG), raised triglycerides (TRG), raised blood pressure [systolic blood pressure (SBP), diastolic blood pressure (DBP)] and reduced high density lipoprotein cholesterol (HDL-C) [5].

E. Anthropometric Measurements

Anthropometric measurements were performed by a trained staff. Weight, height, WC, HC, NC were determined and recorded for calculations. For the measurement of height, a portable stadiometer was used. The child was in standing upright position with no shoes. The horizontal bar of the stadiometer was lowered to the top of the head. The measurement was read to the nearest 0.1 cm. For the weight measurement, a portable digital medical scale was used. The child was in light underwear. The weight was measured to the nearest 0.1 kg. A non-stretchable anthropometric measuring tape was used for the measurement of waist, hip and NCs. WC was measured over the naked skin. The minimum circumference was taken between the lowest rib and the iliac crest. HC was measured as the largest circumference of the buttocks. Clothes with belts and pockets were avoided. Readings were recorded to the nearest 0.1 cm. NC was measured just below the larynx perpendicular to the longitudinal axis of the neck. Readings were recorded to the nearest 0.1 cm.

F. Blood Pressure Measurements

Systolic and diastolic blood pressure (BP) values were determined and recorded for calculations.

An upper arm BP device (sphygmomanometer; ERKA BP monitoring), adequate cuff and pediatric stethoscope were used to determine BP values of the children. The child was in sitting position during the measurement.

Child's feet were on the floor and child's elbow is at about heart level. Talking was prevented. The cuff was placed on naked skin.

G. Laboratory Data

Blood samples used in routine biochemical tests including FBG, TRG, HDL-C were obtained after an overnight fasting. Analyses were performed by the automated analyzer. The values were recorded for calculations.

H. Index Calculations

BMI values were calculated using weight and height of the children (kg/m^2). The developed formula for ADCI was the product of WC and HC divided by NC (WC*HC/NC).

I. Statistics

The statistical package SPSS was used for the analysis of the study data. Mean values with standard deviations of the measured parameters were calculated by descriptive statistics. The differences between the groups were investigated by compare means analysis. Correlation-regression tests were performed. Regression plots were drawn. The p values less than 0.05 were judged as significant.

III. Results

Commonly used anthropometric index BMI and the anthropometric measurements e.g. WC and NC, which find independent use in clinical studies, were given in Table I. In this table, mean ± SD values of a composite index, ADCI, were also shown.

TABLE I
COMMONLY USED ANTHROPOMETRIC PARAMETERS AND ADVANCED DONMA CIRCUMFERENCE INDEX (MEAN ± SD)

	Group 1	Group 2	Group 3	Group 4	p
BMI	17.7 ± 2.8	24.5 ± 3.3	28.8 ± 5.7	31.4 ± 8.0	1-2,2-3 *
WC	62.5 ± 9.2	82.2 ± 10.6	91.4 ± 12.9	100.8 ± 21.9	1-2, 2-3, 3-4 *
HC	76.5 ± 12.4	94.4 ± 13.2	101.0 ± 14.4	106.2 ± 15.3	1-2, 2-3 °
NC	29.2 ± 4.2	32.4 ± 3.1	34.4 ± 4.0	36.0 ± 5.1	1-2*
ADCI	*165* ± 35	240 ± 42	270 ± 55	298 ± 62	1-2 *,2-3, 3-4°

Group 1 = N- BMI, Group 2 = obese, Group 3 = morbid obese, Group 4 = MetS
* = p = 0.01, ° = p = 0.05

NC differed only between group 1 and group 2. BMI and HC differed between group 2 and 3 as well as group 1 and 2. There was no significant difference between group 3 and 4. WC and ADCI were significantly different between Group 1 and 2, 2 and 3 and 3 and 4. To find the parameter showing the best performance, the correlations between each of these two parameters (WC and ADCI) and INS, SBP and DBP values were compared.

In MetS group, any significant correlation was not found between WC and each of these three parameters. However, statistically significant correlations were observed between ADCI and INS (r = 0.353; p = 0.044), SBP (r = 0.696; p = 0.001) and DBP (r = 0.624; p = 0.001). When all cases were considered, correlation coefficients between ADCI and BMI as well as WC were calculated as 0.883 and 0.765 (p = 0.001), respectively. The plot concerning the correlation between BMI and ADCI, which considers all of 187 cases was shown in Fig. 1.

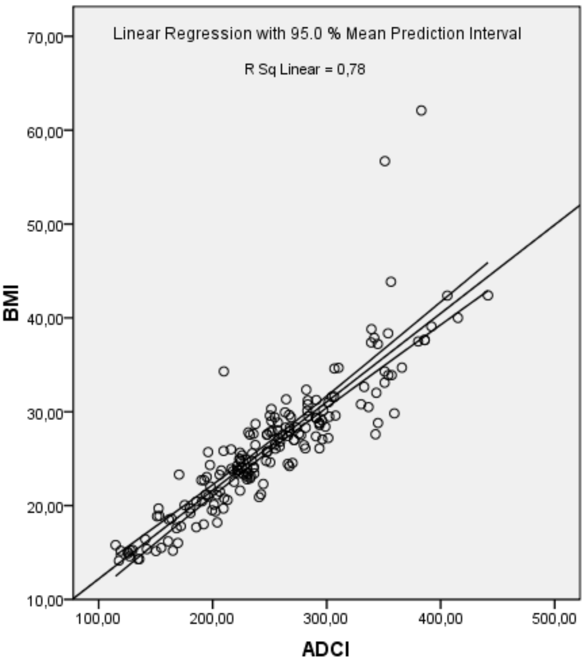

Fig. 1 Regression plot between BMI and ADCI drawn for the study population

IV. Discussion

BMI, WC, HC and NC are the most commonly used simple and practical anthropometric measurements particularly in obesity studies. They are non-invasive and low-cost parameters, which can be used as the indicators of central obesity and cardiometabolic risk (CMR) in children and adolescents [22].

WC and NC can also be used independently and are capable of giving useful information in research as well as clinical studies. Both appear to be useful for the identification of obese cases. In a study, NC was reported as the parameter with better performance than WC in the assessment of metabolic health in individuals with severe obesity [24]. In another study, NC was introduced as a good discriminator of overweight and obesity in women [25].

Waist and HC s were commonly used together. These two parameters may serve as alternative predictors of visceral fat accumulation in T2D [21]. Consideration of both may be helpful for the identification of individuals at increased risk of death [19]. However, their use in the form of waist-to-hip ratio is much more common [22].

Waist and HCs measure different aspects of body composition and fat distribution. They may have independent and opposite effects. A narrow waist and a large hip may both protect against CVDs [20]. However, it was also reported that among overweight and obese adults with increased CMR, reducing excess adipose tissue provides health benefits regardless of its origin [26].

In this study, the anthropometric parameters and the indices derived from these parameters were compared between groups. Particularly, the differences between MO and MetS groups were investigated for possible differential diagnosis. Besides, the potential associations between these parameters/ indices and MetS-related components such as BPs, lipids, glucose and INS were examined to determine the parameter/ index with the best performance. The index, which is presented in this study, showed higher performance in the MetS group than other parameters due to its close associations with INS, SBP and DBP.

V. Conclusion

In this study, the index derived from three independently functional anthropometric measurements was presented. BMI, which is composed of weight and height, reflected excess weight rather than excess fat. The product of WC and HC divided by NC showed outstanding performance in the differential diagnosis of morbid obesity from obesity and MetS.

References

[1] P. Piqueras, A. Ballester, J. V. Durá-Gil, S. Martinez-Hervas, J. Redón, and J. T. Real, “Anthropometric indicators as a tool for diagnosis of obesity and other health risk factors: A literature review. *Front. Psychol.,* vol.12, 631179, Jul. 2021.

[2] M. F. Rolland-Cachera, M. Semp,é, M. Guilloud-Bataille, E. Patois, F. Péquignot-Guggenbuhl and V. Fautrad, “Adiposity indices in children,” *Am. J. Clin. Nutr.,* vol.36, pp.178–184, 1982.

[3] S. Lemieux, D. Prud'homme, C. Bouchard, A. Tremblay and J. P. Després, “A single threshold value of waist girth identifies normal-weight and overweight subjects with excess visceral adipose tissue,” *Am. J. Clin. Nutr.,* vol.64, pp.685–693, 1996.

[4] M. Heo, G. C. Kabat, D. Gallagher, S. B. Heymsfield and T. E. Rohan, “Optimal scaling of weight and waist circumference to height for maximal association with DXA-measured total body fat mass by sex, age and race/ethnicity,” *Int. J. Obes.,* vol.37, pp.1154–1160, 2013.

[5] P. Zimmet, K. G. AlbertiG, F. Kaufman, N. Tajima, M. Silink, S. Arslanian, G. Wong, P. Bennet, J. Shaw, S. Caprio, and IDF consensus group, “The metabolic syndrome in children and adolescents-an IDF consensus report,” *Pediatr. Diabetes,* vol.8, no.5, pp. 299-306, 2007.

[6] L. Ben-Noun, E. Sohar and A. Laor, “Neck circumference as a simple screening measure for identifying overweight and obese patients,” *Obes. Res.,* vol.9, pp. 470–477, 2001.

[7] M. R. Hingorjo, M. A. Qureshi and A. Mehdi, “Neck circumference as a useful marker of obesity: a comparison with body mass index and waist circumference,” *J. Pak. Med. Assoc.,* vol.62, pp.36–40, 2012.

[8] J. Aswathappa, S. Garg, K. Kutty and V. Shankar, “Neck circumference as an anthropometric measure of obesity in diabetics,” *North Am. J. Med. Sci.,* vol.5, pp.28–31, 2013.

[9] D.-H. Lou, F.-Z. Yin, R. Wang, C.-M. Ma, X.-L. Liu and Q. Lu, “Neck circumference is an accurate and simple index for evaluating overweight and obesity in Han children” *Ann. Hum. Biol.,* vol.39, pp.161–165, 2012.

[10] Expert Panel on Detection, Evaluation and Treatment of High Blood Cholesterol in Adults, “Executive summary of the third report of the national cholesterol education program (NCEP) expert panel on detection, evaluation, and treatment of high blood cholesterol in adults (adult treatment panel III),” *JAMA,* vol.285, pp.2486–2497, 2001.

[11] K. G. M. M. Alberti, P. Zimmet and J. Shaw, “Metabolic syndrome–a new world-wide definition. a consensus statement from the international diabetes federation,” *Diabet. Med. J. Br. Diabet. Assoc.,* vol.23, pp.469–480, 2006.

[12] M. C. Pouliot, J. P. Després, S. Lemieux, S. Moorjani, C. Bouchard and A. Tremblay, “Waist circumference and abdominal sagittal diameter: best simple anthropometric indexes of abdominal visceral adipose tissue accumulation and related cardiovascular risk in men and women,” *Am. J. Cardiol.,* vol.73, pp.460–468, 1994.

[13] T. S. Han, E. M. van Leer, J. C. Seidell and M. E. Lean, “Waist circumference action levels in the identification of cardiovascular risk factors: prevalence study in a random sample, *BMJ,* vol.311, pp.1401–1405, 1995.

[14] K. M. Rexrode, V. J. Carey, C. H. Hennekens, E. E. Walters, G. A. Colditz and M. J. Stampfer, "Abdominal adiposity and coronary heart disease in women," *JAMA,* vol.280, pp.1843–1848, 1998.
[15] C. J. Dobbelsteyn, M. R. Joffres, D. R. MacLean and G. Flowerdew, "A comparative evaluation of waist circumference, waist-to-hip ratio and body mass index as indicators of cardiovascular risk factors. The Canadian heart health surveys," *Int. J. Obes. Relat. Metab. Disord. J. Int. Assoc. Study Obes.,* vol.25, pp.652–661, 2001.
[16] J. M. Chan, E. B. Rimm, G. A. Colditz, M. J. Stampfer and W. C. Willett, "Obesity, fat distribution, and weight gain as risk factors for clinical diabetes in men," *Diabetes Care,* vol.17, pp.961–969, 1994.
[17] V. J. Carey, E. E. Walters, G. A. Colditz, C. G. Solomon, W. C. Willett and B. A. Rosner, "Body fat distribution and risk of non-insulin-dependent diabetes mellitus in women. the Nurses' Health Study," *Am. J. Epidemiol.,* vol.145, pp.614–619, 1997.
[18] M. Wei, S. P. Gaskill, S. M. Haffner and M. P. Stern, „Waist circumference as the best predictor of noninsulin dependent diabetes mellitus (NIDDM) compared to body mass index, waist/hip ratio and other anthropometric measurements in Mexican Americans–a 7-year prospective study," *Obes. Res.,* vol.5, pp.16–23, 1997.
[19] A. J. Cameron, H. Romaniuk, L. Orellana, J. Dallongeville, A. J. Dobson, W. Drygas, M. Ferrario, J. Ferrieres, S. Giampaoli, F. Gianfagna, L. Iacoviello, P. Jousilahti, F. Kee, M. Moitry, T. J. Niiranen, A. Pająk, L. Palmieri, T. Palosaari, M. Satu, A. Tamosiunas, B. Thorand, U. Toft, D. Vanuzzo, S. Veikko, G. Veronesi, T. Wilsgaard, K. Kuulasmaa and S. Söderberg, "Combined influence of waist and hip circumference on risk of death in a large cohort of European and Australian adults," *J. Am. Heart Assoc.,* vol.9, no.13, pp.e015189, Jul. 2020.
[20] J. C. Seidell, L. Pérusse, J. P. Després and C. Bouchard, "Waist and hip circumferences have independent and opposite effects on cardiovascular disease risk factors: the Quebec Family Study," *Am. J. Clin. Nutr.,* vol.74, no.3, pp.315-321, Sep. 2001.
[21] B. Eghan, F. Yeboah, E. Togbe, M. Annani-akollor, S. Donkor and B. Afranie, "Waist circumference and hip circumference as potential predictors of visceral fat estimate among type 2 diabetic patients at the Komfo Anokye Teaching Hospital (KATH), Kumasi-Ghana," *Alexandria J. Med.,* vol.55, pp.49-56, 2019.
[22] Z. Kułaga, A. Świąder-Leśniak, A. Kotowska and M. Litwin, "Population-based references for waist and hip circumferences, waist-to-hip and waist-to-height ratios for children and adolescents, and evaluation of their predictive ability," *Eur. J. Pediatr.,* vol.182, pp.3217–3229, May 2023.
[23] WHO World Health Organization. The WHO Child Growth Standards. Available at: http://www.who.int/childgrowth/en/ Accessed on June 10, 2016.
[24] Y. Assyov, A. Gateva, A. Tsakova, and Z. Kamenov, "A comparison of the clinical usefulness of neck circumference and waist circumference in individuals with severe obesity," *Endocr. Res.,* vol.42, pp. 1-9, 2016.
[25] D. R. Petreça, E. C. Menezes, P. F. Sandreschi, F. Fank and G. Z. Mazo, "Neck circumference as a discriminator of obesity in older women enrolled in a physical activity program," *Braz. J. Kinathrop. Hum. Perform.,* online. 2017, vol. 19, no. 6, pp. 710-719, 2017 Accessed 25 July 2023.
[26] P. M. Janiszewski, J. L. Kuk, and R. Ross, "Is the reduction of lower-body subcutaneous adipose tissue associated with elevations in risk factors for diabetes and cardiovascular disease?," *Diabetologia,* vol.51, pp. 1475–1482, 2008.